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X-601-77-33  
PREPRINT

TMX-71278

PREDICTION AND MEASUREMENT  
RESULTS OF RADIATION DAMAGE  
TO CMOS DEVICES ON BOARD  
SPACECRAFT

(NASA-TM-X-71278) PREDICTION AND  
MEASUREMENT RESULTS OF RADIATION DAMAGE TO  
CMOS DEVICES ON BOARD SPACECRAFT (NASA) S P  
HC A02/MF A01

CSCL 22B

N77-19162

Unclass  
G3/19 21285

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MAR 1977  
RECEIVED  
NASA STI FACILITY  
INPUT BRANCH

FEBRUARY 1977



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GREENBELT, MARYLAND

PREDICTION AND MEASUREMENT RESULTS OF RADIATION DAMAGE TO CMOS  
DEVICES ON BOARD SPACECRAFT

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Summary

In a previous paper<sup>1</sup> a detailed description was given of: (a) the CMOS Radiation Effects Measurement (CREM) experiment, presently being flown on the Explorer-55; (b) the associated on-the-ground simulation experiment with a Co-60 source; (c) the calculation of the predicted dose levels in the CREM flight experiment, based on standard environment models; and (d) the method of comparing the flight data with the associated measurements and predictions made on the ground. In addition, some partial, preliminary results, uncorrected for temperature effects, of biased RCA n-channel devices located in the CREM device box in the surface of the spacecraft were also given, covering only the time interval up to the 180th day in orbit.

Since more data has been received in the interim from the spacecraft, in this paper we present: (a) all the currently available results of the flight experiment for all the individually instrumented 130 transistors, relating to both biased and unbiased n- and p-channel RCA and p-channel AMI devices, and (b) the predictions of dose levels based on a detailed analysis of the space radiation environment as encountered by Explorer-55 and calculated by: (1) one dimensional slab geometry, and (2) three dimensional spherical geometry (with Monte Carlo correction for electrons). These predictions are made for five sample locations on the spacecraft: four in the CREM device box, mounted flush in the surface of the spacecraft, and each with a different predetermined aluminum shield, and the fifth in a typical location of an electronic box in the interior of the spacecraft. The flight data, as received from space and calibrated with the on-the-ground simulation experiment, are compared to the predicted values.

For this evaluation, four mission dates were chosen, which reflect significant changes in the orbit of the spacecraft, thereby

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<sup>1</sup>1976, same conference: IEEE Transactions on Nuclear Science, Vol. NS-23, #6, p. 1781, December 1976

changing correspondingly its radiation exposure: May 11, 1976 - orbit stabilization (after 174 days in orbit), August 1, 1976 - begin second interval of orbit decay (after 256 days in orbit), November 19, 1976 - orbit circularization (after 366 days in orbit), and April 30, 1977 - last day of data to be processed for this report (after 498 days in orbit). These mission dates are indicated on Figures 1 through 3.

Figure 1 gives an example of the energetic particle intensities calculated for the actual Explorer-55 trajectory with standard environment models. The flight data are corrected for the temperature variation on the spacecraft. Examples of flight data with temperature corrections are given in Figure 2, which shows the shifts in the threshold potentials ( $10 \mu\text{A}$  drain current) of the biased RCA n-channel devices under the four aluminum shields and in the typical location of electronic instruments in the interior of the spacecraft. Since the shifts in the threshold potentials of the unbiased n-channel and both biased and unbiased p-channels are small in comparison to the biased n-channels, the temperature corrections in this case make a substantial contribution to the accuracy of the results. Figure 3 shows the results of biased AMI p-channel devices. As seen from the error bars, the results of these devices are less accurate than those of biased n-channels of RCA and clearly exhibit the previously determined error of  $\pm 20 \text{ mV}$  of the on-board data acquisition and telemetry systems.

The summary of the flight results of n- and p-channel devices of both biased and unbiased mode is given in Table 1 for the four mission dates. The results are calculated from flight data by comparing the space effects to the data of the on-the-ground simulation experiment. Each value represents an average for all transistor types and biasing modes for a given shield configuration.

Because the required trajectory ephemeris for the mission dates considered in this paper is only gradually being made available from the tracking and telemetry computers of Explorer-55, the environment determination progresses at a corresponding rate. Subsequent device performance predictions and correlations for these dates are being processed concurrently and will be presented fully at the time of the conference.

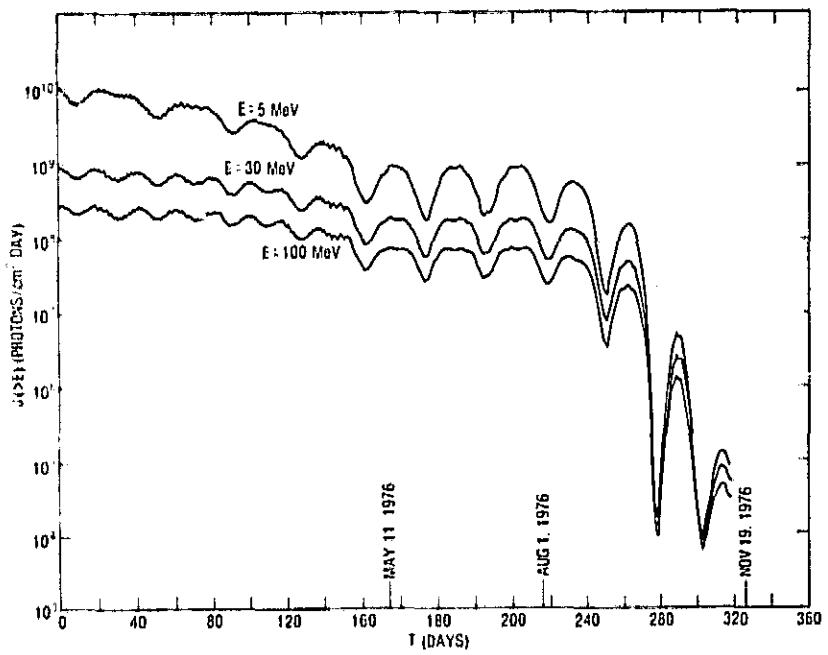


Figure 1. Time history of mission integrated, omnidirectional, trapped proton fluxes.

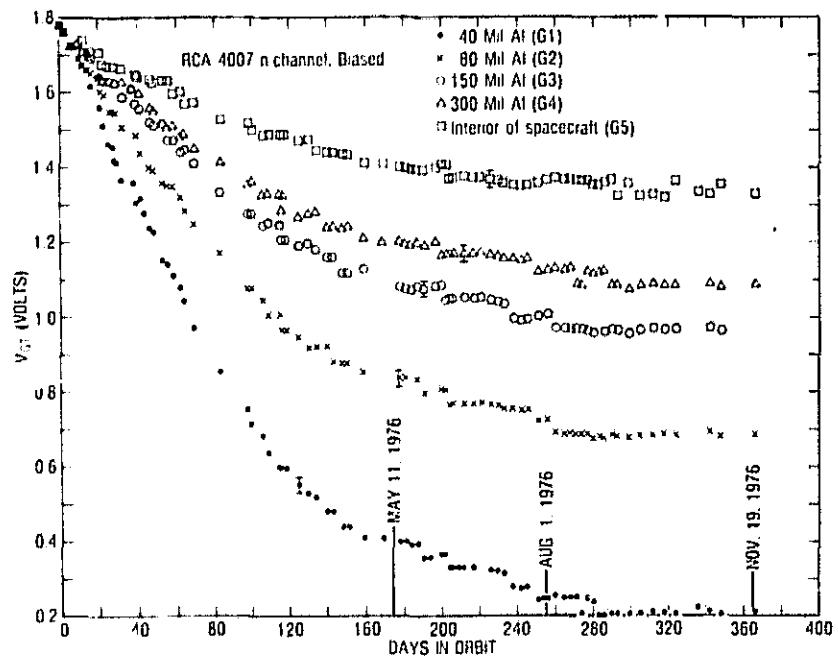


Figure 2. Flight data results of RCA n-channel devices, corrected for temperature variation, under the four aluminum shields and in the interior of the spacecraft.

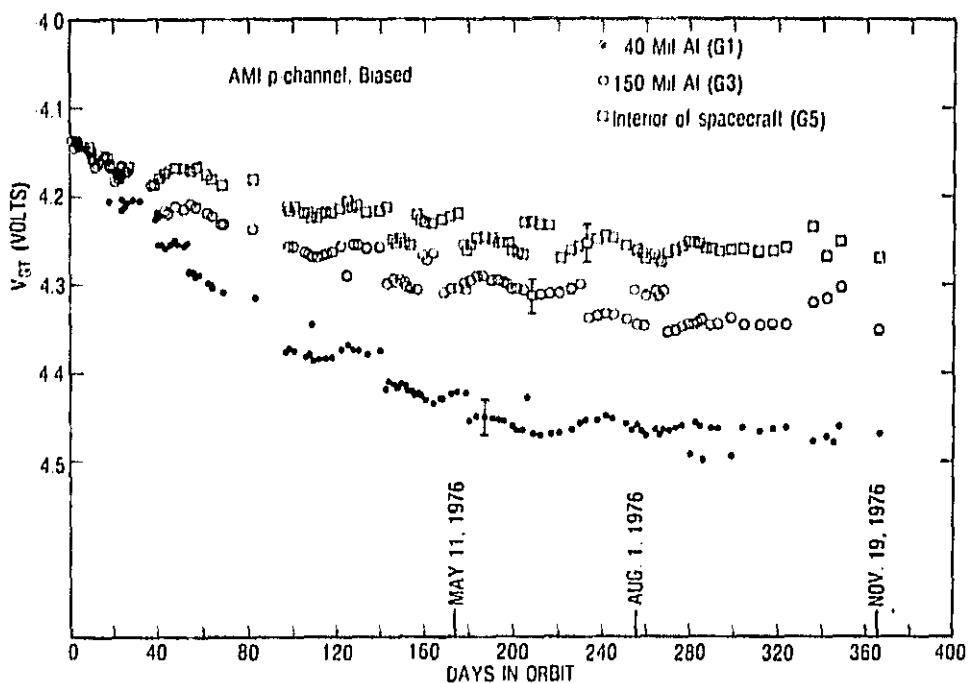


Figure 3. Flight data results of AMI p-channel devices, corrected for temperature variation, under two aluminum shields and in the interior of the spacecraft.

Table 1. Total accumulated dose levels in rad-Si. The values are averages over all the devices under each shield configuration (group).

Mission date	Group 1 40 mils Al (1.02 mm)	Group 2 80 mils Al (2.03 mm)	Group 3 150 mils Al (3.81 mm)	Group 4 300 mils Al (7.62 mm)	Group 5 Interior of spacecraft
May 11, 1976 174 days in orbit	$8.57 \times 10^3$	$6.53 \times 10^3$	$5.38 \times 10^3$	$4.68 \times 10^3$	$3.07 \times 10^3$
Aug. 1, 1976 256 days in orbit	$9.58 \times 10^3$	$7.39 \times 10^3$	$6.21 \times 10^3$	$5.35 \times 10^3$	$3.63 \times 10^3$
Nov. 19, 1976 366 days in orbit	$9.85 \times 10^3$	$7.62 \times 10^3$	$6.35 \times 10^3$	$5.61 \times 10^3$	$3.74 \times 10^3$
Apr. 30, 1977 498 days in orbit					